UNITED
NATIONS

E

Economic and Social Council

Distr.
LIMITED

E/CONF.83/L.29
21 January 1991

ENGLISH ONLY

TWELFTH UNITED NATIONS REGIONAL
CARTOGRAPHIC CONFERENCE FOR ASIA
AND THE PACIFIC
Bangkok, 20-28 February 1991
Item 7 (b) of the provisional agenda*

CARTOGRAPHIC DATA RETRIEVAL, ANALYSIS, DEPICTION, PRESENTATION AND PRODUCT GENERATION: DIGITAL DATA BASES

Implementing a cartographic database to enable automation

Paper submitted by the United States of America**

* E/CONF.83/1.

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The Aeronautical Chart Branch (ACB) of the National Ocean Service is beginning to automate the production of some of its charts. The transformation of the production process is an ongoing effort, depending on human considerations and technical factors for success. Currently, production techniques for ACB's products range from traditional manual compilation, engraving, and stick-up to the use of various levels of computer-assisted cartographic tools. Each chart series, with its standard scale, complexity of feature representation, revision cycle, and other characteristics, poses more or less of a challenge in the process of automation.

This paper describes the extent of current automation at ACB and evaluates the feasibility of introducing further automated solutions with regard to various types of charts. By implementing a cartographic database, using a commercially available relational database management system, increased efficiency and flexibility can be realized in the production of a significant number of charts. The paper summarizes the concepts that define a cartographic database and how these concepts serve to resolve problems of redundancy in the revision of charts, increase flexibility in the creation of new products, and enable the automatic flow of cartographic information from the database to the digital chart product.

Finally, the paper presents an overview of the operation of a commercial cartographic database developed for production of aeronautical charts by the Intergraph Corporation. It describes the software components of the Intergraph Aeronautical Charting System (IACS) to be installed by ACB and provides a scenario of the cartographer's interaction with the system, emphasizing the expansion of his responsibilities in controlling the automated compilation process.

IMPLEMENTING A CARTOGRAPHIC DATABASE TO ENABLE AUTOMATION

As a result of four years of aggressive acquisition and development of new hardware and software systems, the Aeronautical Chart Branch (ACB) is ready to implement state-of-the-art cartographic automation. Expanding the use of the computer to assist its traditional cartographic compilation and production methods throughout this period of development, the ACB can now take the next step--linking its volatile databases of aeronautical information directly to the production of digital maps. By doing so, ACB will position itself to automate the physical production of feature negatives and many aspects of the compilation process itself. Benefits accruing to ACB from the automation of these processes would be significant.

Expediting the logistics of maintaining more than 8,000 charts, most subject to revision every 56 days, automation will permit less rigid scheduling and coordination. By eliminating the scribing or stick-up of feature overlays from the production cycle of many charts, automation will also eliminate much of the present dependence on contractor turnaround to complete the cycle. Beyond its cost-effectiveness, automation will serve ACB by enabling it to satisfy growing demands for cartographic digital interfaces from other organizations and from consumers.

Since the success of the automation depends on an understanding of what is being automated, the report will review the traditional, manual techniques currently being used. The report will then trace the initial progress already made toward automation and will describe what further steps remain to be taken to develop a more fully automated system. Methods being implemented by other cartographic organizations approaching automation will be presented to provide a sense of the state-of-the-art. Finally, the report will deal specifically with the Intergraph Aeronautical Charting System--the next phase in ACB's ongoing efforts to automate the production of aeronautical charts.

Cartographers now access numerous hard-copy source documents, including notices, reference manuals, and existing maps, in the process of compiling a chart. Some hard-copy source material is provided them by the Aeronautical Information Section in the form of computer generated listings, calculations, and schematic plots. Painstakingly, manually transferring feature information from these source documents, properly positioning and symbolizing it, the compiler creates a hard-copy "standard", the annotated map manuscript used by contract agency technicians to create or revise the stable plastic film feature overlays that the basemap comprises. Increasingly, as ACB has expanded its aeronautical

information database, the cartographer has used feature data derived from its files as input to computer graphics programs that produce quality-control plots against which the manually compiled map standard may be checked. Only rarely, however, can a computer generated plot be used to produce a feature negative directly.

The compiled map standards and the basemaps produced from these standards exist in purely physical form. Considering the collection of basemaps for all of ACB's published charts to represent a physical (or analog) "database" is useful. Such a "database," however, whether in digital or analog form, remains a discrete collection of maps. Having no unifying relationship between its components, it will not serve as a database of map information from which full automation can proceed. Nonetheless, by converting some of the maps from analog to digital format, ACB has accomplished considerable automation of certain elements of the production process.

The first step toward automation was taken in 1987 with the decision to convert more than 2,000 Radar Video Maps (RVMs) into digital format. The RVMs are not published but are produced as photonegatives, reduced, and ultimately projected on the video screens of Airport Surveillance Radar equipment. Besides being atypical of ACB's chart products in form, they differ significantly in specification of their content and are unique in having only one feature negative. The specification of feature presentation on an RVM is not standard across the map series, but varies according to the needs of the particular air traffic control center requesting the map. The area of chart coverage is limited and the presentation of features simplified, so that a cartographer familiar with the operation of the graphics workstation can digitize an existing RVM in 4 to 8 hours (Bolton and Hoover 9).

In producing the digital maps, cartographers have predictably found the operation of the Intergraph workstations and the application of Intergraph's graphic software--Interactive Graphic Design System (IGDS) and World Mapping System (WMS)--straightforward--"a nearly direct translation of existing manual operations to the computer" (Calkins and Marble 105). By letting cartographers create the RVM basemaps digitally, ACB has enabled automation of the production of the photonegative. The digital compilation has replaced both the hard-copy standard previously used to specify the engraving of the basemap, and the engraved basemap itself. The photonegative is now produced directly from the digital chart and is plotted on-site with a high-precision, Gerber photo-plotter. The manual engraving procedure, with its

lengthy turnaround time, has been completely eliminated, reducing the time required for revision or creation of an RVM from several weeks to a week or even days (Bolton and Hoover 10).

Recently ACB has begun to widen its application of the Intergraph system to produce digital charts of greater complexity. Four new charts of the Enroute Low Chart Series have been created. The workstations, each with a capacity to represent 63 separate design file overlays, have easily managed the task of separating the features of the digital basemaps. As with the RVMs, the creation of the new Enroute Low Alaska charts was mostly accomplished interactively by cartographers at the workstations using computer assisted methods analogous to manual techniques.

Because the products of the compilation process for these charts were themselves digital files, other digital files could often be directly incorporated into the compilation, bypassing the traditional manual transfer of information from hard-copy source documents (Thornburg). Geographic coordinates of features maintained in ACB's general aeronautical database, CONDOR, for example, were extracted into digital files in a separate process. At the workstation, using WMS, the cartographer was able to access these files directly and use them to place fully symbolized features in the digital maps. Although the Alaska Enroute charts were not, in fact, used to produce photographic feature overlays directly, the potential for doing so was clearly demonstrated (Thornburg).

ACB has used digital maps to eliminate the need to manually engrave or stick-up features on basemap overlays and even to make the compilation process itself more efficient. It now plans to establish a unified cartographic database from which dynamically linked digital charts can be derived and maintained and, thus, to achieve the full potential of cartographic automation (Bundock 294-295).

Considering ACB's collection of analog and digital basemaps as a "database" of map information, it is apparent that such a collection is far from unified. A feature occurring on more than one chart is represented more than once in the "database", and may be represented differently in each "database" occurrence. The same real, geographic feature, for example, appearing on both an Instrument Approach Procedure (IAP) chart and an Enroute chart may be shown on each chart at a different scale. Revision of the feature entails two separate basemap revisions, with each revision varying according to the scaled representation of the feature. The symbol for another feature, such as an airport, may be shown in blue or brown on an Enroute chart and in black on a

Standard Terminal Arrival (STAR) chart. On a Sectional chart, the same airport feature may be shown by a different symbol entirely--again, necessitating more than one revision and more than one type of revision.

Developing a unified cartographic database (CDB) dynamically linked to the digital chart products derived from it, will help eliminate the problem of multiple revisions for a single feature. Any change, addition, or deletion to the CDB will automatically propagate from the database to the individual charts derived from the database on which the feature occurs. The revision of each feature occurrence will be in accordance with the defined specifications for scale and symbolization of the feature for the chart containing the occurrence.

These cartographic specifications, and others, will themselves be part of the CDB, and, by their inclusion in that database, will link the CDB to each of the digital charts. A CDB can be created using one of the commercially available database management systems (DBMS):

> Many of the above problems can be solved using any one of a number of commercially available database management systems. Hence it is proposed that a DBMS be utilized to manage not only the geographic attribute data, but also the cartographic data. The data defining the cartographic entities to be displayed can be managed within a DBMS in much the same way as any other data. (Bundock 295)

While the revision process will become more efficient with such a system, the design process will also become more flexible. New charts, at larger scales, representing portions of existing maps are sometimes required to relieve feature congestion in the smaller scale existing maps. Projects such as the redesign of the H3 Northeast Enroute chart and creation of the H6 Eastcoast Enroute chart would be accomplished more easily and quickly since feature data would exist in the CDB "seamlessly", independently of any chart boundaries, and could be extracted to fit any chart configuration at any scale.

Other organizations attempting cartographic automation based on these principles include the Nautical Chart Branch of the National Ocean Survey, and Jeppesen Sanderson, Inc., a private aviation chart producer.

The Nautical Chart Branch (NCB) is currently developing the prototype for its Automated Nautical Charting System (ANCS II).

Intergraph Corporation is providing NCB with workstations, graphics software, and a cartographic database design based on the commercially available relational DBMS, Oracle (Poltivolo).

The NCB will maintain two databases. The Nautical Information Data Base, a general purpose database, will be used to derive and maintain the separate Chart Graphics Data Base (Smith 1374).

A private, commercial organization, Jeppesen Sanderson, Inc., has used Intergraph systems in its production of IAPs and Enroute charts for several years. Its current software system, now providing many automated capabilities, will soon be superseded by Intergraph's recently developed, third generation aeronautical charting product, Intergraph Aeronautical Charting System--IACS (Kelly). The production process now, as demonstrated in their promotional videotape (Jeppesen Sanderson, Inc.), involves the transfer of updated aeronautical information from a general purpose database maintained on a VAX 11/750 to an Intergraph processing system dedicated to the maintenance of the digital charts. Updates applying to each chart are interactively validated or rejected by compilers at workstations connected to the Intergraph processor. The compilers interpret the update status of each chart feature on the basis of its displayed color, with red indicating deletion from the database, yellow indicating a change, etc. Once all database generated revisions have been either validated, modified, or rejected, a hard-copy, electrostatic print is made of the workstation display on a Versatec V80 plotter and given to another compiler for quality-control review. Finally, a copy of the digital chart is put on magnetic tape and transferred to a Scitex laser-plotter system which uses the digital chart to produce high-resolution film positives or negatives suitable for reproduction.

To achieve its automation goals as efficiently as possible, ACB also plans to install the Intergrapn Aeronautical Charting System. IACS uses existing hardware and software, including Ingres, WMS, and IGDS. Ingres has already been installed for other purposes and is being developed to provide a general aeronautical information database, similar to CONDOR but more powerful and flexible. This database will remain distinct from the cartographic database but eventually may be used to update it. With Ingres, IGDS, and WMS software currently operational, no great financial outlay will be required to provide the initial environment in which to develop prototype applications of IACS.

ACB's cartographers have already used WMS and IGDS software at the workstations and will be familiar with these components of the IACS system. They will not have had experience with Ingres,

the relational database that constitutes the third component of the IACS system. Intergraph, however, has designed a user-friendly, form-driven menu to the Ingres cartographic database that will make it more accessible (Intergraph Corp. 1:7-9).

Initially, both the features depicted in the charts and the specifications defining each chart will need to be established in the cartographic database. Aeronautical Chart Automation Section cartographers and computer specialists will work closely with cartographers in other Sections to accomplish this. Much feature data in the charts may need to be digitized manually in the WMS environment. Other feature data used to populate the database may be derived from existing CONDOR files. Chart specifications will need to be entered interactively through IACS's forms-driven interface to Ingres.

After the CDB has been populated, the cartographer will be able to generate charts from it and maintain digital charts previously generated. Beyond the need to define new chart specifications, there will be little difference between the procedures for creating a new chart or for maintaining an existing chart with IACS (Intergraph Corp. 6:1-11).

In maintaining a chart, the cartographer will receive an IACS generated report identifying any changes to it subsequent to any update of the CDB. Whenever the decision is made to compile these pending changes to the chart, the compiler activates IACS, identifying the chart and initiating the batch extraction of updated feature data to be applied to it from the CDB. On completion of the extraction process, the compiler initiates another IACS process to automatically symbolize the extracted feature data according to the specifications of the chart. The symbolized, updated data is then automatically incorporated into the digital chart. At the workstation, the cartographer makes final judgements on the disposition of any of the displayed pending changes. Here too, the cartographer's judgement must be exercised in cleaning up the chart to final standards.

IACS is not an "expert system." Such systems have not developed sufficiently to replace human skill and knowledge in the field of cartography (Gallant 386). Many situations will arise requiring deletion, displacement, or other modification of features included automatically in the digital compilation. Considering the critical application for which the aeronautical chart product is designed, the need for human validation of changes propagated automatically will be of increased, not diminished importance at ACB.

Chart series considered as candidates for IACS need to be evaluated for ease of original conversion and for adequacy of feature coverage in the general aeronautical database to be used to update the CDB. Since the demands placed on graphics workstations and photoscribing equipment will increase with the automation of more charts, the time required to produce charts of varying complexity using these limited resources must also be considered in the cost-effectiveness equation. The production of Radar Video Maps has already undergone partial automation. At some point, these maps may be considered candidates for IACS. Priority now, however, should be given to commercial charts produced on short, regular cycles. The cost-effectiveness of pipelining the flow of information from database to chart will be greater the more frequently and extensively the chart must be revised.

Sectional and Terminal Area Charts are revised every 6 months and are rich in topographic feature detail. The topographic features, derived primarily from U.S. Geological Survey 7 1/2-minute quadrangle maps, are not supported by the aeronautical database, making the full automation of these series unlikely. In the future, however, it may prove feasible to maintain aeronautical feature overlays for these charts using an automated system while continuing to maintain the topographic overlays of the basemaps manually (Tamm-Daniels, Cooper, and McCollough 514).

The primary candidates for IACS automation are the Enroute and IAP charts. These chart series are maintained on 56 day cycles. Presentation of topographic feature data is extremely limited. The Enroute charts are the more complex charts, consisting of twenty or more feature overlays. The monochromatic IAP charts have only three overlays, cover smaller geographic areas, and are physically smaller (about 5 x 7 inches). Photoscribing new feature negatives and reviewing new chart prints for charts of the size and complexity of the Enroute charts will be time-consuming. To reduce demands on equipment and personnel, photoscribing of new negatives could be limited by continuing to make minor modifications to film overlays by hand after having first established these modifications in the digital map through IACS.

The charts that will most easily be adapted to IACS are the IAPs. In the initial conversion process, these charts will probably require about the same amount of time to digitize as the RVMs. With few overlays, small in size, and limited in complexity and coverage, they could be completely photoscribed and reviewed every 56 days. Their short revision cycle takes full advantage

of the automated flow of update information from the CDB. The cost benefits from automation of the IAPs may even prove greater than those shown for the RVM series because of the greater frequency of revision and greater degree of automated compilation that will be introduced for the IAPs.

Development of automated cartographic production, beginning with the conversion of the IAP Chart Series, will be a cooperative endeavor involving the efforts of both cartographers and computer specialists. Once established, IACS will not eliminate the role of the cartographer from the compilation process. Instead, that role will expand to include new responsibilities in the operation and monitoring of the system.

WORKS CITED

Bolton, Ronald M., and Russel A. Hoover. "Automated Radar Video Map Production at NOS." Aeronautical Charting Division, National Ocean Service, National Oceanic and Atmospheric Administration. Oct. 1987.

Bundock, M.S. "An Integrated DBMS Approach to Geographical Information Systems." Auto-Carto 8 Proceedings, Baltimore, MD. 29 Mar. to 3 Apr. 1987. Falls Church: ASPRS/ACSM, 1987, 292-301.

Calkins, Hugh W., and Duane F. Marble. "The Transition To Automated Production Cartography: Design Of The Master Cartographic Database." The American Cartographer 14.2 (1987): 105-119.

Gallant, David G. "The Misguided Evolution of Future Mapping Technology." Auto-Carto 8 Proceedings, Baltimore, MD. 29 Mar. to 3 Apr. 1987. Falls Church: ASPRS/ACSM, 1987.

Intergraph Corp. Intergraph Aeronautical Charting System (IACS) Reference Manual. Huntsville: Intergraph Corp., 1989.

Jeppesen Sanderson, Inc. N.t. (Promotional material on automated chart production), n.d., videotape.

Kelly, David W. Software Scientist, Intergraph Corporation. Telephone interview, 26 Feb. 1990.

Poltivolo, David. Graphics Manager, Nautical Chart Branch, National Ocean Survey, National Oceanic And Atmospheric Administration. Personal interview, 26 Mar. 1990.

Smith, Norman D. "Automated Nautical Data and Charting Development." Oceans' 88 Proceedings 4. New York: IEEE, 1988, 1374-1378.

Tamm-Daniels, Frederick L., John R. Cooper, Jr., and Major C.R. McCollough. "The Automated Revision of Tennessee Valley Topographic 1:24,000 Quadrangles." Auto-Carto 7 Proceedings, Washington, D.C. 11 Mar. to 14 Mar. 1985. Falls Church: ASP/ACSM, 1985, 514-522.

Thornburg, Tim. Cartographer, Aeronautical Chart Automation Section, Aeronautical Charting Division, National Ocean Survey, National Oceanic And Atmospheric Administration. 2 Apr. 1990.

APPENDIX A

GLOSSARY OF TERMS

Analog - Representing data by physical quantities. For example, the geographic distance between two locations is represented as a scaled analog distance on a map.

Basemap - The collection of photographic, engraved, or digital feature overlays that are used to create the photographic plates for lithographic reproduction of a map.

Batch processing - Computer processing occurring independently of any current session at the computer terminal, a background job.

Chart - A map used in navigation.

Compilation - The process of assembling, organizing, and laying out data to create or revise a map, or the layout manuscript itself.

Compiler - The cartographer who makes a compilation.

Database - A collection of data organized for retrieval as useful information.

Digital - Defined by numerical units. For example, computer data is defined by binary (0's and 1's) digital data.

Digitize - To convert to digital form. For example, at a graphics workstation, an analog map can be converted into a digital file.

Enroute Chart - Aeronautical chart that is used by pilots to navigate with information obtained from instrument readings and radio contact.

Expert system - A computer system that makes complicated decisions to resolve certain problems based on logic developed by human experts.

Feature - A manmade or natural phenomenon depicted on a map. For example, the prescribed flight path between two cities is an aeronautical feature, while the cities themselves are topographic features.

File - An organization of digital data created by and accessed by a computer.

Graphics workstation - A type of computer terminal that allows digital data to be created, modified, and displayed as visual patterns. The techniques used to create or modify the digital graphic display appear to the user to be similar to manual graphic techniques.

Instrument Approach Procedure Chart - Aeronautical Chart that is used by pilots making an approach to landing based on instrument readings and radio contact.

Interactive processing - Computer processing that requires connection of the user to a computer through a session at a terminal.

Laser-plotter - A plotter that uses a laser beam to expose a photographic negative.

Overlay - The collection of all map features of a similar type on a sheet of semi-transparent plastic film, or the collection of all such features on a transparent, electronic, digital display. The set of layered plastic film sheets or digital displays for all the features shown on the map is the "basemap".

Photo-plotter - A plotter that uses a light beam to expose a photographic negative.

Photoscribe - To expose a photographic negative using a laser-plotter or photo-plotter.

Plot - To use a file of digital information as input to a plotter to produce lines on paper, photographic negatives, or other material.

Plotter - The output device that translates a digital graphics file into a visual design on paper or other material.

Processor - A computer.

Relational database - A type of digital database that depends on existing similarities of data to find relationships between different subsets of the data.

Scribing - Engraving of lines on a coated sheet of plastic film.

Sectional Chart- Aeronautical chart used by pilots navigating by topographic landmarks.

Stick-up - Attaching pre-printed symbols, lines, and text to feature overlay sheets.

Symbol - A graphic design used to represent a feature on a map.

Symbolize - To represent a feature on a map using a symbol.

Terminal Area Chart - Aeronautical chart covering the geographic area of an airport terminal, similar to a Sectional Chart but larger in scale.

Topographic- Pertaining to the configuration of a surface, such as the surface of the earth.